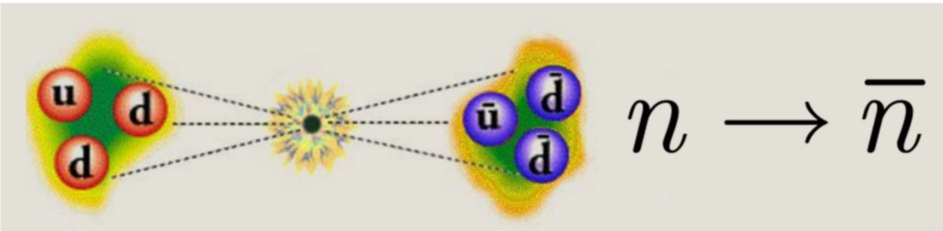
Theoretical Innovations for Future Experiments Regarding Baryon Number Violation, Part 1

Monday 03 August 2020 - Friday 07 August 2020



Book of Abstracts

An Amherst Center for Fundamental Interactions Workshop

In coordination with Snowmass 2021 Rare Processes and Precision Measurements Frontier: Topical Group on Baryon & Lepton Number Violation (RP4)

The overarching topic of the workshop is the violation of Baryon-minus-Lepton ($\mathcal{B}-\mathcal{L}$) number. $\mathcal{B}-\mathcal{L}$ number is exactly conserved in the Standard Model, but the observed matter-antimatter asymmetry of the universe hints that beyond the Standard Model $\mathcal{B}-\mathcal{L}$ violating processes could exist. Proton decay (PDK) experiments set very strong limits on $\mathcal{B}$-violating interactions (though most conserve $\mathcal{B}-\mathcal{L}$), pointing towards very high-energy scales around 10^{13} TeV; however, models exist where the proton is stable while $\mathcal{B}$ is still not a good symmetry (for instance, if $\mathcal{B}$ is only violated by two units, i.e. $\Delta\mathcal{B} = 2$). Such models lead to unique and powerful experimental signatures such as the transformations of neutrons into antineutrons ($n \to \bar{n}$, similar to kaon-antikaon oscillations due to strangeness-changing weak interactions) or decays of otherwise stable nuclei via dinucleon annihilation.

Recent years have seen significant theoretical developments of various aspects of these intriguing scenarios, and models have been created that naturally avoid PDK limits while solving other problems within the Standard Model such as the matter-antimatter asymmetry of the universe. Lattice-QCD calculations have made tremendous improvements in calculating QCD matrix elements that connect $\mathcal{B}$-violating quark interactions to observables. Studies in effective field theories for B-violating nuclear interactions have been initiated and applied to light nuclei, while novel intranuclear simulations have been developed to assess whether dinucleon decay processes can be separated from background in medium-heavy nuclei. At the same time, the prospects for future experiments look good: The European Spallation Source, DUNE, PNPI Gatchina, and Hyper-Kamiokande are all expected to attain significantly increased sensitivities to $\mathcal{B}-\mathcal{L}$ violation.

Despite these recent exciting developments, the collective particle, lattice-QCD, nuclear, and experimental communities are currently rather disjoint and do not meet very often (if at all) to discuss strategy and theoretical necessities for mutualistic progress in the field. A major goal of this workshop is to bring together representatives across these communities to discuss what major challenges exist, what the prospects are for discovering $\Delta\mathcal{B} = 2$ violation in future experiments, and the interpretation of experimental signals or limits in the broader context of $\mathcal{B}-\mathcal{L}$ violation.

Furthermore, the US particle physics community is preparing to identify and rank scientific priorities with the goal of shaping the physics program for the next few decades as part of the Snowmass process, which will initiate in the next year. A summertime workshop frame ensures that we can better serve the experimental community interested in BNV by surveying

Contents

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Overview of some recent theoretical developments in neutron oscillation

Corresponding Author: rmohapat@umd.edu

There are a number of puzzles of beyond the standard model physics that can be probed directly by the process of neutron-anti-neutron oscillation in contrast with the othetr popular baryon violating process i.e. the typical GUT motivated proton decay mode $p \to e^{+0}$. The most important of them is a direct understanding of the baryon asymmetry of the universe on which the typical GUT motivated baryon violation cannot. Also if neutron oscillation is observable, leptogenesis mechanism also does not work. The mechanism for such baryogenesis is the post sphaleron model which implemented in the context of $SU(2)_L \times SU(2)_R \times SU(4)_C$ model for neutron oscillation leads to an upper limit on neutron-antineutron oscillation time within the reach of currently proposed experiments. Furthermore, if neutrino-less double beta decay fails to yield a positive signal, an alternative way to establish that lepton number is violated and neutrinos are their own antiparticles is to discover both proton decay and neutron oscillations. Also the belief that neutrinos are likely to be Majorana fermions strongly suggests that there may be a small Majorana component to the neutron mass which leads to neutron oscillation. All these arguments provide strong arguments for a new search for neutron-anti-neutron oscillation. In the second part of the talk, I point out some constraints arising from big bang nucleosynthesis that suppress the neutron mirror neutron oscillation which is under study in several experiments.

Contribution Title:

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Some Recent Results on Models with $n-\bar{n}$ Oscillations

Author: Robert Shrock[None]

Co-authors: Sudhakantha Girmohanta [1]; Shmuel Nussinov [2]

[1] *Stony Brook University*

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We discuss models that can feature $n-\bar{n}$ oscillations at observable levels. These are extra-dimensional theories with Standard-Model fermions propagating in the extra dimensions. Interestingly, while proton decay can be suppressed well below experimental limits in these models, $n-\bar{n}$ oscillations can occur at levels comparable to current limits. Thus, in these theories, $n-\bar{n}$ oscillations and the associated $\Delta B=-2$ dinucleon decays can be the dominant manfestation of baryon-number violation. Analyses are given within the context of a Standard-Model effective field theory and a theory involving a left-right symmetry group.

Contribution Title:

Some Recent Results on Models with $n-\bar{n}$ Oscillations

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The European Spallation Source and Future Free Neutron Oscillations Searches

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The European Spallation Source ESS, presently under construction, in Lund, Sweden, is a multidisciplinary international laboratory. It will operate the world's most powerful pulsed neutron source. Taking advantage of the unique potential of the ESS, the NNBAR collaboration proposed a two-stage program of experiments to perform high precision searches for neutron conversion in a range of baryon number violation (BNV) channels culminating in an ultimate sensitivity increase for $n \to \bar{n}$ oscillations of three orders of magnitude over the previously attained limit obtained at the Institut Laue-Langevin ILL.
The first stage of this program HIBEAM (High Intensity Baryon Extraction and Measurement) will employ the fundamental physics beamline during the first phase of the ESS operation. This stage focuses principally on searches for neutron conversion to sterile neutrons n'. The second stage, NNBAR will exploit the Large Beam Port (LBP), a unique component of the ESS facility to search directly for $n \to \bar{n}$.
In the talk, I will briefly discuss the scientific motivations for these searches, the status of the the European Spallation Source and the recent developments in the HIBEAM/NNBAR Collaboration.

Contribution Title:

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Neutron-antineutron oscillation search at Super-Kamiokande

Author: Linyan WAN[1]

[1] *Boston University*

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As a baryon number violating process with $\Delta B = \Delta(B-L) = 2$, neutron-antineutron oscillation ($n \to \bar{n}$)provides an important candidate and a unique probe to the baryon asymmetry. We performed a search for $n \to \bar{n}$ oscillation with the Super-Kamiokande (SK) experiment. Full exposure data set of SK was analyzed using a multi-variate analysis based on kinematic variables and basic distributions from simulated $n \to \bar{n}$ signal events and atmospheric neutrino backgrounds. We observed 11 events, compared with the expected number of background events 9.3. The upper limit of nuclear lifetime is calculated as 3.6×10^{32} years at 90% CL, significantly improved from the present best-limit 1.9×10^{32} years of SK-I.

Contribution Title:

Neutron-antineutron oscillation search at Super-Kamiokande

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Search for $n \to \bar{n}$ in the Deep Underground Neutrino Experiment

Authors: Yeon-jae Jwa[1]; Joshua Barrow[2]

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The Deep Underground Neutrino Experiment (DUNE) utilizes Liquid Argon Time Projection Chamber (LArTPC) technology to deeply probe ν and beyond Standard Model (BSM) interactions with great granularity. The DUNE Technical Design Report (TDR) prioritizes BSM searches for baryon number violation (BNV) modes such as proton decay and neutron-antineutron transformation ($n \to \bar{n}$), showing expected lower limit targets for DUNE. The previous DUNE analysis techniques used for DUNE's $n \to \bar{n}$ target will be highlighted, as well as ongoing studies utilizing similar procedures which move toward understanding intranuclear modeling systematics related to this unknown rare process.

Contribution Title:

Studies for Expected Lower Limits of Bound Neutron-Antineutron Transformation in the Deep Underground Neutrino Experiment

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Possible Use Of Neutron Optics for Optimization of a Free Neutron-Antineutron Oscillation Search

Author: William Snow[1]

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Neutron-antineutron oscillations can survive sufficiently coherent interactions with matter and external fields without suppressing the oscillation rate. I describe some examples of this phenomenon which might find practical applications
in the design of future experiments.

Contribution Title:

Possible Use Of Neutron Optics for Optimization of a Free Neutron-Antineutron Oscillation Search

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Baryon-number violation by two units in chiral effective field theory

Authors: Bingwei Long[None]; Femke Oosterhof[None]; Jordy de Vries[None]; Rob Timmermans[None]; Ubirajara van Kolck[None]

I discuss a framework based on chiral effective filed theory for treating baryon-number violation by two units in nuclei. The deuteron lifetime is used as an application to illustrate this framework. The emphasis is given to how a consistent power counting is built and what statements can be drawn out of it.

Contribution Title:

Baryon-number violation by two units in chiral effective field theory

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Calculation of the Suppression Factor for Bound Neutron-Antineutron Transformation

Author: Jean-Marc Richard[1]

[1] *IP2I,, IN2P3, U. of Lyon*

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I review and revisit the calculation of the lifetime of nuclei due to neutron-antineutron oscillations. It is stressed that the oscillation and the subsequent annihilation take place mainly outside the nucleus and thus hardly suffer from drastic renormalization due to the nuclear medium. The ingredients of the calculation can be safely extracted from nuclear shell-model wave-functions, and optical models fitting the low-energy data on antinucleon-nucleus interaction. The main result is that the lifetime of a nucleus behaves as $T = T_R\,\tau_{n\bar{n}}^2$, with a factor T_R, often referred to as *reduced lifetime* or *suppression factor* of about $10^{22-23}\,\mathrm{s}^{-1}$. A remarkable feature is that T_R is stable against variations of the antinucleon-nucleus potential.

Contribution Title:

Calculation of the Suppression Factor for Bound Neutron-Antineutron Transformation

Discussions / 29

Differences in Intranuclear Suppression Factors: Why? How is it important?

Authors: Jean-Marc Richard[1]; Bingwei Long[2]

[1] *IP2I,, IN2P3, U. of Lyon*

[2] *Sichuan University*

Corresponding Authors: j-m.richard@ipnl.in2p3.fr, bingwei@scu.edu.cn

The following questions are often raised when discussing the neutron-antineutron oscillations nuclei:

- How well is known the nucleon-antinucleon interaction?
- How well is known the antinucleon-nucleus interaction?
- Is the shell model an appropriate tool?
- How comes that the neutron-antineutron oscillation takes place mainly at the surface of the nucleus?
- What type of final state is expected for antineutron-nucleus annihilation arising from neutron oscillation?

The above issues, and others, will be adressed during the discussion session.

Contribution Title:

Differences in Intranuclear SuppressionFactors: Why? How is it important?

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Lattice QCD matrix elements of Delta B = 2 operators

Author: Michael Wagman[None]

Co-authors: Sergey Syritsyn ; Enrico Rinaldi ; Chris Schroeder ; Michael Buchoff ; Joseph Wasem

Theories of B-L violation beyond the Standard Model (BSM) generically lead to the appearance of six-quark operators in Standard Model effective field theory that give rise to neutron-antineutron oscillations and Delta B = 2 nuclear decays. Reliably connecting the results of experimental searches for these processes to constraints on the parameters of BSM physics theories requires Standard Model calculations of the matrix elements of these six-quark operators between hadronic states. I will report on lattice quantum chromodyanmics calculations of a complete basis of Delta B = 2 six-quark operators and a few of their implications for current and future searches for Delta B = 2 processes.

Contribution Title:

Lattice QCD matrix elements of Delta B = 2 operators

12

Update on the post-sphaleron baryogenesis model prediction for neutron-antineutron oscillation time

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Post-sphaleron baryogenesis (PSB) is an attractive low-scale mechanism to explain the observed matter-antimatter asymmetry of the Universe. The same \Delta B=2 operator that gives rise to baryogenesis in this scenario also leads to neutron-antineutron oscillation. We show that the PSB mechanism, when embedded in a quark-lepton unified model based on the Pati-Salam gauge group, leads to an absolute upper limit on the neutron-antineutron oscillation time, which might be within reach of future experiments. The multi-TeV-scale scalar diquarks in this model could also be searched for at the LHC and future hadron colliders.

Contribution Title:

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Probing High Scale Theories with $n - \bar{n}$ Oscillations

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$n-\bar{n}$ oscillations can be used to probe theories at a high energy scale, such as grand unified theories. In this talk I will illustrate this with two examples. In the first example, $n - \bar{n}$ oscillation arises in a left-right symmetric model realized near the GUT scale that provides a solution to the strong CP problem. The $n - \bar{n}$ oscillation time is closely tied to neutrino masses, and is expected to be in the range of $10^8 - 10^{10}$ sec. In the second example, $SO(10)$ grand unified theory breaks to the standard model directly, but leaves behind a color sextet scalar field at the TeV scale. This scalar helps with unification of gauge couplings and leads to $n - \bar{n}$ oscillations, which is closely tied to baryon asymmetry generation. For typical values of the model parameters, $\tau_{n-\bar{n}} \sim 10^9 - 10^{10}$ sec. is obtained.

Contribution Title:

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Neutron-antineutron oscillation improvements and baryogenesis

Author: James Wells[None]

Wherein I discuss how improvements on neutron-antineutron oscillations and its impact on a minimal theory of baryogenesis.

Contribution Title:

Neutron-antineutron oscillation improvements and baryogenesis

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Search for NNbar with UCN

Authors: Alexey Fomin[1]; Anatolii Serebrov[1]; Mikhail Chaikovskii[1]; Oleg Zherebtsov[1]; Aleksandr Murashkin[1]; Elena Golubeva[2]

[1] *NRC "Kurchatov Institute" - PNPI*

[2] *INR RAS*

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The scheme of the experiment on search for neutron-antineutron oscillations based on the storage of ultracold neutrons in a material trap is presented. The idea of such an experiment becomes important due to creation of new powerful UCN sources. The sensitivity of the experiment was obtained in Monte Carlo simulation of UCN transport and storage. It mostly depends on the trap size and the amount of UCN in it. Design of the setup, magnetic shielding study, neutron storage and annihilation detection simulations are presented. The possibilities of increasing the sensitivity of the experiment due to the accumulation of the antineutron phase in the collisions of neutrons with the walls are considered.

Contribution Title:

Search for NNbar with UCN

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New scenario for the neutron–antineutron oscillation: shortcut through mirror world

Author: Zurab Berezhiani[1]

[1] *University of L'Aquila*

Corresponding Author: zurab.berezhiani@aquila.infn.it

Existing bounds on the neutron-antineutron mass mixing, $\epsilon_{n\bar{n}} <$ few $\times 10^{-24}$~eV, impose a severe upper limit on $n-\bar{n}$ transition probability, $P_{n\bar{n}}(t) < (t/0.1\text{ s})^2 \times 10^{-18}$ or so, where t is the neutron flight time. Here we propose a new mechanism of $n-\bar{n}$ transition which is not induced by direct mass mixing $\epsilon_{n\bar{n}}$ but is mediated instead by the neutron mass mixings $\epsilon_{nn'}$ and $\epsilon_{n\bar{n}'}$ with the hypothetical states of mirror neutron n' and mirror antineutron $\bar{n}'$ which can be as large as $\sim 10^{-14}$~eV or so,

without contradicting the present experimental limits and nuclear stability bounds. The probabilities of $n-n'$ and $n-\bar{n}'$ transitions, $P_{nn'}$ and $P_{n\bar{n}'}$, depend on environmental conditions in mirror sector, and by scanning over the magnetic field values in experiments they can be resonantly amplified. This opens up a possibility of $n-\bar{n}$ transition with the probability $P_{n\bar{n}} = P_{nn'}P_{n\bar{n}'}$ which can reach the values up to $\sim 10^{-8}$. For finding this effect in real experiments, the magnetic field should be suppressed but properly varied. This scenario points towards the scale of few TeV of new physics which can be responsible for these mixings, and can also suggest a new low scale co-baryogenesis mechanism between ordinary and mirror sectors.

Contribution Title:

New scenario for the neutron–antineutron oscillation: shortcut through mirror world

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Search for neutron oscillations to a sterile state ($n \rightarrow n^{'}$) and to an antineutron ($n \rightarrow \overline{n}$)

Author: Yuri Kamyshkov[1]

[1] *University of Tennessee*

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As follows from theoretical conjectures of Z. Berezhiani et al. [2006-2020] the neutron that is part of the Standard Model (SM) can oscillate into sterile state $n \rightarrow n^{'}$, thus leading to neutron disappearance or baryon number violation $\Delta B = -1$. However, this can be only an apparent disappearance: if the sterile neutron $n^{'}$ is part of the Mirror Standard Model ($SM^{'}$) with corresponding mirror baryon number $B^{'}$ the transformation $n \rightarrow n^{'}$ can occur without violation of the global baryon number $\Delta\left(B+B^{'}\right) = 0$. This process will be not necessarily suppressed by high mass scale and can have observable probability corresponding to oscillation times as small as 1-100 s. The $SM^{'}$ sector is assumed to be an exact copy of SM with the same particle content and the same gauge interactions within $SM^{'}$, but these interactions are absent between SM and $SM^{'}$ particles, e.g. mirror photon $\gamma^{'}$ will not interact with SM charges and vice versa. The gravity however is a common interaction for both sectors thus making $SM^{'}$ a good candidate for the Dark Matter. Also, additional new BSM interactions are conjectured that mix the neutral particles of SM and $SM^{'}$ sectors (like γ, ν, n and possibly other neutral particles) that makes such interactions responsible for the direct detection of DM and for transformations like $\gamma \rightarrow \gamma^{'}$, $\nu \rightarrow \nu^{'}$, and particularly interesting $n \rightarrow n^{'}$, as a most convenient for experimental observation process.
Existing neutron sources provide cold neutron beams with high intensities that can be used for rather simple and inexpensive experimental searches like $n \rightarrow n^{'}$ disappearance, $n \rightarrow n^{'} \rightarrow n$ regeneration, searches for neutron transition magnetic moment, and neutron – antineutron transformations through mirror-state oscillations $n \rightarrow n^{'} \rightarrow \overline{n}$. Plans for such measurements with existing neutron sources at the Oak Ridge National Laboratory and at the future European Spallation Source and the sensitivity reach will be discussed in the workshop presentation.

Contribution Title:

Search for neutron oscillations to the sterile state $n \rightarrow n^{'}$ and to antineutron $n \rightarrow \overline{n}$

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Neutrons at ORNL and ESS: A Synergistic Program

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Oak Ridge National Laboratory has some of the world's most advanced neutron sources, the High Flux Isotope Reactor (HFIR) which is a continuous source of neutrons from nuclear fission, and the Spallation Neutron Source, a pulsed source created by an accelerated proton beam hitting a mercury target. Not only are both good sources for neutrons, they are also excellent neutrino sources with exceptional characteristics. An ambitious and growing fundamental neutron and neutrino science program is in operation at both the SNS and HFIR. Both facilities will undergo major upgrades. A Second Target Station will be built at the SNS, driven by a 2.8MW proton beam, and HFIR will be upgraded with a new pressure vessel and reflector. This provides a unique and timely opportunity to explore the opportunities these upgraded facilities offer for a compelling future fundamental physics program. The Physics Division invites the community to develop a strong synergistic program.

Contribution Title:

Discussions / 17

(Suggested Discussion) Snowmass Strategies: Past and Present

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Contribution Title:

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Searches for scalars that carry B or L, taken broadly: whither and wherefore

Author: Susan Gardner[1]

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Corresponding Author: svg@pa.uky.edu

In many models of new physics, the expected rate of processes that break baryon number by two units rests on the features of a poorly known scalar sector, whose members can carry B or L quantum numbers. Thus the BNV discovery prospects in these channels are controlled by the extent to which the associated scalars are excluded by experiments. Working in the context of minimal scalar models, I will survey and discuss the existing constraints and note what windows of opportunity remain for the discovery of light new scalars. With these, new experiments become tenable, and I emphasize the complementary of these to other ongoing efforts and their broader implications.

Contribution Title:

Searches for scalars that carry B or L, taken broadly: whither and wherefore

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Covering baryon number violation with inclusive searches

Author: Julian Heeck[1]

[1] *UC Irvine*

Corresponding Author: jheeck@uci.edu

Baryon number violation is an extremely sensitive probe of physics beyond the Standard Model. However, the continued absence of any signals raises the question if we are actually looking in the right places or if we should broaden our search strategies. In this talk I will propose *inclusive* nucleon decay searches as a convenient method to cover a lot of parameter space, including sensitivity to new light particles and dark matter induced baryon number violation.

Contribution Title:

Covering baryon number violation with inclusive searches

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Measurements of Neutron Coupling to a Mirror Sector Using Spin Precession

Author: Albert Young[1]

[1] *North Carolina State University/Triangle Universities Nuclear Laboratory*

Corresponding Author: aryoung@ncsu.edu

Couplings between neutrons and a mirror sector can be formulated in terms of observable effects for precession-measurements (as has been pointed out by Berezhiani), bringing to bear the tools and experimental resources already in play for the measurement of static electric dipole moments.limits for measurements with the coupling strength for neutrons to mirror neutrons. Some details of measurements in an EDM-like geometry can be used to place limits on mirror couplings and provide information on the orientation and strength of a mirror magnetic field, should it exist in the mirror sector.

Contribution Title:

Measurements of Neutron Couplings to a Mirror Sector Using Spin Precession

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Exciting New Possibilities for Baryon Number Violation

Author: Sudhakantha Girmohanta[1]

Co-author: Robert Shrock [2]

[1] *Stony Brook University*

[2] *C. N. Institute for Theoretical Physics, Stony Brook University*

Corresponding Authors: robert.shrock@stonybrook.edu, sudhakantha.girmohanta@stonybrook.edu

Proton decay can be sufficiently suppressed in an extra-dimensional model where Standard-Model (SM) fermions are localized at different points in the extra dimension(s), whereas n-$\bar{n}$ oscillations can occur at a rate comparable to the current observable limit. We show that in a left-right symmetric model with extra dimensions this effect is even more enhanced. Several nucleon and dinucleon decays to leptonic final states are considered in the extra-dimensional framework and found to be sufficiently suppressed. n-$\bar{n}$ oscillations are special in this extra-dimensional framework as separating quark and lepton wavefunctions in the extra dimensions to suppress nucleon and dinucleon decays to leptonic final states does not suppress n-$\bar{n}$ oscillations, which only involve quarks.

Contribution Title:

Exciting New Possibilities for Baryon Number Violation

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Perspectives on Baryon Number Violation

Author: David McKeen[1]

[1] *TRIUMF*

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In this talk I discuss baryon number violation and the relationship between processes that violate it by one or two units. While proton decay searches currently probe baryon number violation by one unit up to very high scales, those that violate it by two units can be directly motivated by the baryon asymmetry of the universe and can be the leading baryon number violating signal in some models. I will also describe some recent work involving new signatures of baryon number violation such as the decay of atomic hydrogen.

Contribution Title:

Perspectives on Baryon Number Violation

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Probing high scale theories through $n-\bar{n}$ oscillations

Author: K.S. Babu[1]

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Corresponding Author: babu@okstate.edu

$n-\bar{n}$ oscillations can be used to probe theories at a high energy scale, such as grand unified theories. In this talk I will illustrate this with two examples. In the first example, $n-\bar{n}$ oscillation arises in a left-right symmetric model realized near the GUT scale that provides a solution to the strong CP problem. The $n-\bar{n}$ oscillation time is closely tied to neutrino masses, and is expected to be in the range of $10^8 - 10^{10}$ sec. In the second example, $SO(10)$ grand unified theory breaks to the standard model directly, but leaves behind a color sextet scalar field at the TeV scale. This scalar helps with unification of gauge couplings and leads to $n-\bar{n}$ oscillations, which is closely tied to baryon asymmetry generation. For typical values of the model parameters, $\tau_{n-\bar{n}} \sim 10^9 - 10^{10}$ sec. is obtained.

Contribution Title:

Probing high scale theories through $n - \bar{n}$ oscillations

This workshop was open for all to attend from 10am-2pm EDT, August 3rd-6th. The coorganizers operated an optional Snowmass Letter of Interest (LOI) writing session everyday of the workshop, typically from 2pm-3pm. Zoom was used throughout the workshop to present contributed talks and collectively discuss the writing of an associated LOI; discussion also included plans to develop a theoretically focused Snowmass Contributed Paper to delve into more detail related to the ideas presented at the workshop

Abstract submission was limited to previously agreed participants in light of postponed plans (due to COVID-19) and time limits.

Co-organizers:
Joshua Barrow (University of Tennessee)
Leah Broussard (Oak Ridge National Laboratory)
Jordy de Vries (University of Massachusetts Amherst/Riken Brookhaven)
Michael Wagman (Fermi National Accelerator Laboratory)

Snowmass 2021 Letters of Interest for recommended collaboration and collective iteration by Workshop attendees included:
ACFI Synthesis of Field (edits were active until August 12th at 5pm PDT); *this LOI is presented at the end of this report*
DUNE $\mathcal{B}-\mathcal{L}$ Violation
ESS NNBAR at the Large Beamport
ORNL to ESS $n \to n'$ and $n \to n' \to \bar{n}$ Searches

Workshop recordings, both audio and video as well as chat data, are all available via the cloud for download:
Day 1
Day 2
Day 3
Day 4

Official Workshop Website
Previous Workshop Website (postponed due to COVID-19)